GUIDE FOR SELECTING TYPES OF SPRINKLER IRRIGATION

Equipment and techniques for the application of water by the sprinkler method are so varied that it is impractical to give specific data in an irrigation guide for this method of irrigation.

The following discussion is aimed at giving guidelines for the selection of the type of equipment best suited and design requirements that the selected equipment should meet.

In sprinkler irrigation, the water is sprayed into the air and allowed to fall on the land surface in a uniform pattern at a rate approximately equal to or less than the intake rate of the soil. This method of water application is similar to rainfall.

If the system is properly designed and operated, efficiencies of 65 percent to 75 percent can be obtained. Sprinkler losses are due to evaporation losses in the air by the sprinkler spray, evaporation from the soil surface or moisture intercepted on the leaves during irrigation, and non-uniform distribution due to the sprinkler pattern. Wind distorts the pattern and frequently this results in non-uniform application and efficiencies considerably lower than given above.

Intake rates under sprinkler irrigation do not conform to those for flood or furrow. Tables 5.2 and 5.12 have been prepared as a guide for maximum application rate and a sprinkler system that will apply water at a rate equal to or less than shown in the tables will be satisfactory to use in applying irrigation water.

TYPES OF SPRINKLERS

Application of water to the land by sprinkler systems require some type of water outlets that will distribute the water in a uniform pattern with controlled droplet size. This is accomplished using variations of two basic types of outlet, namely the spray nozzle and the impact sprinkler. By varying spray outlet shape, air mixing, deflectors and operating pressure or varying the nozzle openings size and shape, angle of application and operating pressure on an impact sprinkler the application rate can be matched to that of the soil.

Impact Sprinklers. These sprinklers are the most common application method used in sprinkler irrigation. They operate under a wide range of pressure (20 p.s.i. to 120 p.s.i.) and can apply water in circles having wetted diameters ranging from 20 feet to 400 feet. Using different nozzle size, shape and operating pressure sprinklers can deliver from 0.5 gallon per minute to 600 gallons per minute. Multiple nozzles and changes in nozzle delivery angle can be used to change their performance. Impact sprinklers are used on all types of sprinkler systems both stationary set and continuous move. Because of their wide range of performance characteristics they have been adapted for use on soils with low intake rates (0.20 inches per hour) up to high intake rates and on a wide variety of crops.

Spray Nozzles. Spray nozzles as the name implies spray a continuous pattern of water droplets over a circular area. Their performance is governed by the design of the mixing chamber, outlet opening and deflector system. They operate at low pressures and have small wetted diameters. Their main application is on continuous move center pivot or lateral move systems. Sprays have been placed to operate upright or downward, in multiples on extension booms and on drop pipes. Major advantage of sprays is the low operating pressure (5 p.s.i. to 40 p.s.i.) and the resulting low energy requirement. Major disadvantage is the small application area of sprays and the high application rate related to it, which limits their use to coarser textured soils having higher intake rates or very light irrigations related to initial soil intake rate and temporary surface storage. Another disadvantage is the small droplet size which increases wind drift problems.

TYPES OF SYSTEMS

All irrigation systems use a series of one or more of the above types of sprinklers to distribute the water. Water is conveyed to these sprinklers through either stationary or movable pipelines and the operation of these pipelines determines the type of system employed.

Hand-Moved Systems. The lateral line pipe and sprinklers are set at one location and allowed to remain there until the desired irrigation is obtained. They are then moved by hand from this position to another and the operation repeated. Therefore, this is called a set-type system. Quick-coupled aluminum pipe is the best for most portable laterals. This is generally the cheapest type of system. However, considerable labor is required for moving the pipe. Figure 5.1 shows the general layout and operation of typical set-type distribution systems, one of which is the hand-move. It also shows the water source in the center of the field, although it could be at another point with the main line located through the center of the field. Systems are normally designed to operate at pressures ranging from 20 p.s.i. to 60 p.s.i.

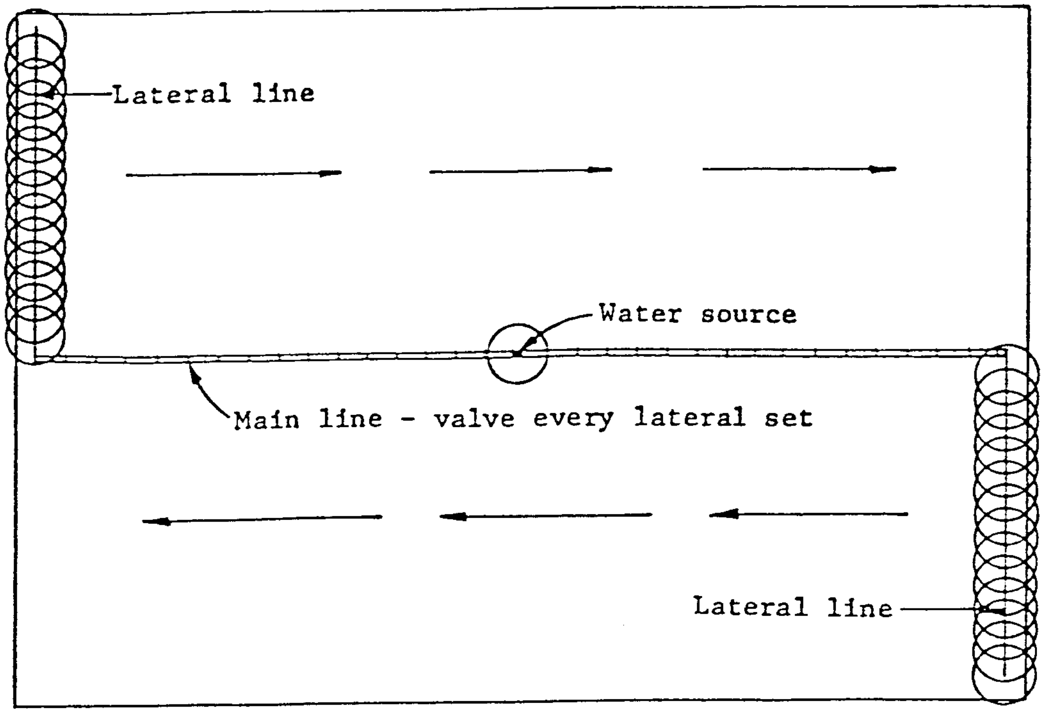


Figure 5.1, Set-type irrigation system

When a lateral line reaches the end of the field, it is disassembled and either moved back to its original location or across the main line to the original location of the other lateral. The lateral lines must be moved to the starting location so that the area which was sprinkled first will again be sprinkled first in the following cycle.

Generally, to keep the labor costs as low as practical, the design should be such that the required irrigation is applied in either a 7- or 11-hour time of set to allow either 3 or 2 sets per day with an hour allowed between each setting for moving the pipe.

<u>Advantages and Limitations</u>. Can be used on irregularly shaped fields and rolling terrain; inconvenient for tall crops. Can use any nozzle from low to high pressure and can meet any intake requirement. It is generally the lowest cost type of sprinkler system with the highest labor requirement.

<u>Side-Roll System</u>. To decrease the amount and intensity of labor required, the lateral line is mounted on wheels. The pipe is the axle with the wheels usually spaced 30 feet apart and the sprinklers midway between. Wheels are available in different diameters with the largest wheels used for the maximum clearance.

The operation of the side-roll lateral is similar to the hand-move system. The lateral line is moved between sets by rolling the wheels. The distance between lateral sets depends on the size of the sprinklers. Usually this distance will be between 60 to 80 feet. The connection of the lateral to the main line is usually made with a 10- to 15-foot section of flexible rubber hose.

When the side-roll system was first available, a larger lever with a ratchet was used to move the system from one set to the next. Today most of the side-roll systems use air-cooled gasoline engines located near the center of the lateral line.

Because the pipe twists somewhat, it is necessary to provide for vertical alignment of the sprinkler. The self-aligner riser is a gooseneck device with a counterweight to keep the sprinkler vertical.

The side-roll system has been modified by some manufacturers by supporting the sprinkler lateral above the wheels of an "A" frame and using a drive shaft to move the system instead of using the pipe as an axle.

For a greater coverage width for a lateral set, side-roll systems have been developed which use trailing sprinkler lines each containing three or four sprinklers. These sprinklers, in addition to the sprinklers located on the main lateral, provide for set distances up to 300 feet. The field operation is the same as a hand-move or the conventional side-roll lateral system, except the coverage distance per set is considerably greater. The operation of this system is shown in Figure 5.2.

When the lateral reaches the end of the field, it has to be moved back to the starting point or to an adjacent field and the trailing lines must be picked up and moved separately. Provision can be made to transport the trailing lines on the main lateral line. These systems often have a main lateral line supported on tower assemblies to provide clearance for tall crops.

Generally, design should be same as for hand-move systems.

<u>Advantages and Limitations</u>: Requires rectangular fields. Except when mounted on tower assemblies, these systems not adapted to tall crops. Can be used on any soil type suitable for sprinkler irrigation. Alignment may be difficult on undulating topography. A commonly used option in operating these systems is to irrigate every other set advancing down the field and irrigating the skipped sets on returning. This eliminates the need for dismantling the system or a long move back to the starting point.

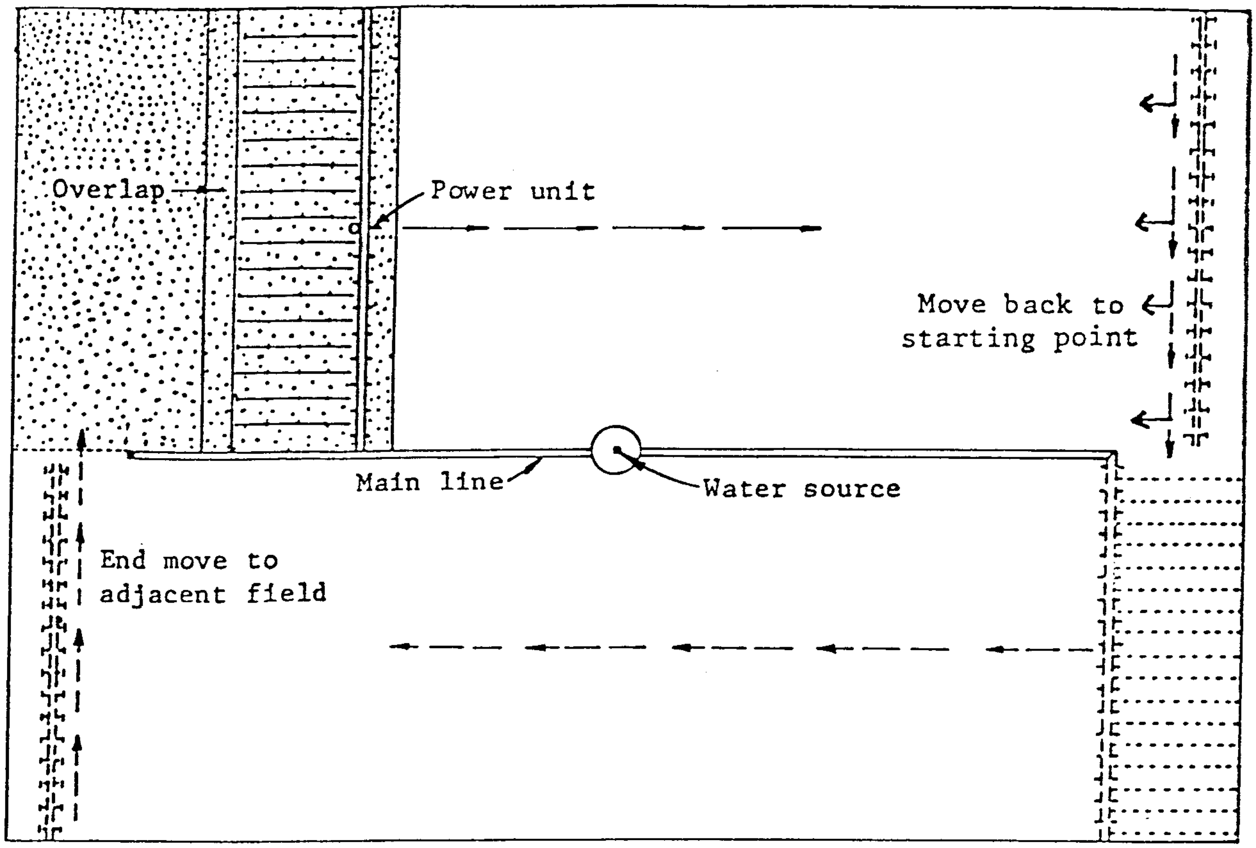


Figure 5.2, Operation of trailing-line system

End-Tow Lateral. Another irrigation system using lateral sets is the end-tow or tractor-move system. The lateral line has couplers semipermanently fastened together. The lateral line may be mounted on skid pans or small wheels to be towed from one set to the next. The operation of a typical end-tow lateral line is shown in Figure 5.3. The main line which supplies the water for the system is located in the center of the field. A turn strip 100 to 200 feet wide is provided so the lateral line can be turned as it is towed from one side of the field to the other. A typical system might have 60-foot sets so the lateral will need to be shifted 30 feet as it crosses the turn strip.

When the lateral reaches the last setting in the field, it will have to be moved back to the starting position--the location of the first set.

To keep the sprinkler risers vertical during sprinkling and while the system is being moved, stabilizers are used on the lateral.

As the lateral is towed across the ground, pipe will wear, depending somewhat on the crop cover and soil texture. Sandy soils which have extremely rough particles will cause the greatest wear. Tow-line couplers usually provide for turning the pipe to distribute the wear around its circumference.

The turn strip may be grass, or some harvestable crop so that this land is not completely lost to production.

Generally design requirements are same as hand-move systems.

Advantages and Limitations: Rectangular fields desirable. Requires 100 feet to 200 feet turnways and narrow alleyways in irrigated row crops. Adapted to any soil type that is suitable for sprinkler irrigation.

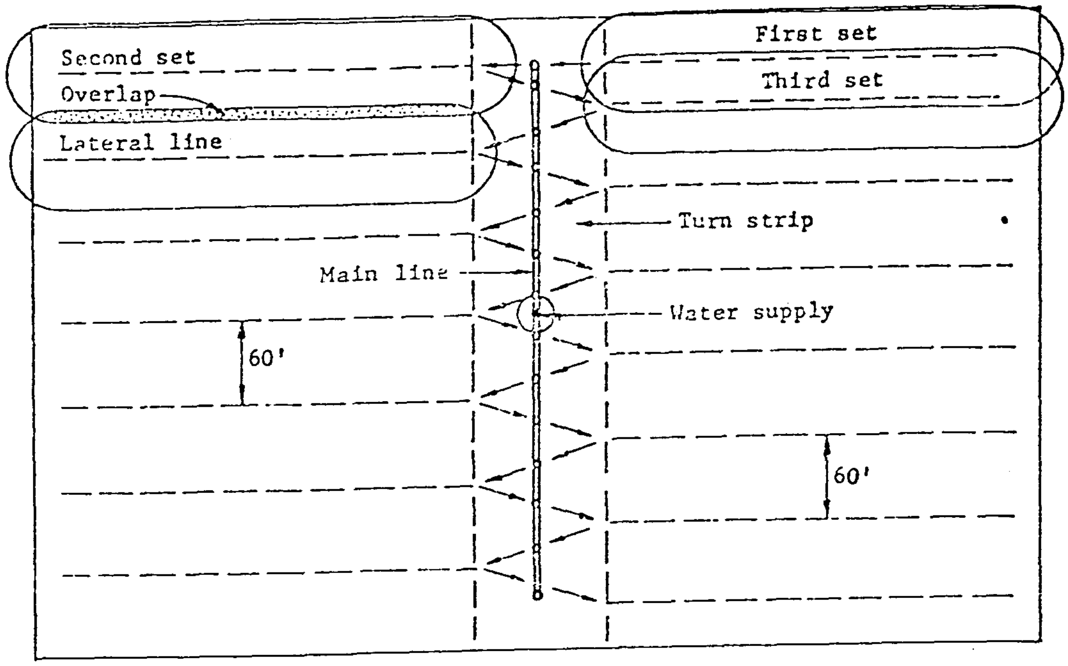


Figure 5.3, End-tow System Operation

Rotating Boom. This system consists of pipe and nozzle arms that rotate about the center or balance point located on a 4-wheel mounted turntable. A tower and cable arrangement hold the boom in place. The boom rotates by water pressure, using a jet action controlled by various nozzle arrangements, nozzle sizes, and variable water pressures. The booms are provided in a choice of lengths providing coverage of about 1 to 4 acres per setting. Application rates vary from about 0.4 to 0.8 inch per hour, with the usual rate being approximately 0.5 inch per hour. The unit can be pulled ahead to a new setting by a tractor attached to the boom carriage by a cable that is sufficiently long so that the tractor operates on dry ground. As the boom moves ahead, the feeder pipeline can be picked up and placed on the trailer that supports the boom. Settings should be such that a triangular pattern results with adjacent lanes.

Because of the large wetted diameter of coverage, there is some problem with wind distortion of the pattern. The long arms help keep this distortion from becoming too severe. However, wind also affects rotation speed of the booms. When the boom arms are at right angles to the wind, rotation speed tends to be slow. Under severe conditions, it may stop when it reaches a position at right angles to the wind. Since the water discharges from the nozzle at a uniform rate, any variation in rotation speed will upset the sprinkler's distribution pattern.

Advantages and Limitations: Rotating boom systems can be used on irregularly shaped fields. Wind affects rotation and water distribution. Requires alleyways for row crops. Application rate is too high for some soils.

Volume Gun. The volume gun sprinkler consists of a single high capacity nozzle mounted on a 2- to 4-wheel trailer. The pump and power unit may also be mounted on the equipment, or it may be permanently placed at a central location. In some types, a tractor is used as the power unit. Volume gun sprinklers are usually larger than 3/4-inch diameter and recommended operating pressures usually exceed 90 pounds per square inch. This pressure will increase the horsepower requirement for the distribution system. When the pressure of the volume gun is below manufacturer's recommendations, water distribution will be uneven.

The wetted diameters of volume guns are extremely large. Because of the large wetted diameter, it is difficult to obtain proper overlap of the sprinkler patterns. Wind distortion of the pattern is also a factor in trying to accomplish good field-wide water distribution. The distance between the lanes should follow the recommendations in Table 5.20 on Page 5-36. The sets should be such that a triangular pattern will result. This gives the best water distribution pattern.

Advantages and Limitations: Volume guns can be used on irregularly shaped fields. Requires high operating pressures. The wind affects water distribution. Requires alleyways for row crops. Have high application rates and, therefore, suited only to relatively high intake rate soils. Application rates generally are in excess of 0.65-inch per hour.

Continuous Move Sprinklers. Both the boom and the volume gun can be operated as continuous move sprinklers. With a flexible supply hose or open ditch to convey water and either a cable with a power winch or a slow moving tractor powered unit, the sprinkler can operate as it moves along a lane. The speed of sprinkler travel can be varied and is adjusted according to the amount of water to be applied. While the water discharge from the sprinkler nozzle is at a constant rate, the amount of irrigation water applied can be varied by the travel speed. Slow sprinkler movement means a relatively large amount of water will be applied to the soil. The speed can also be adjusted so that moving the hose and sprinkler unit from one lane to the next will fit other farm operations.

The flexible hose is available from 2-inch to 5-inch sizes. There is considerable friction loss in the hose which must be overcome by pump pressure. This additional pressure requires additional horsepower and increases the operating cost of the system.

Flexible hose normally requires a hose reel when moving between sets for speed and reduced wear. In addition to having sufficient strength to withstand high operating pressures, the hose must be strong enough to be towed when full of water. Thus, a special type of hose is needed for the continuous move sprinklers. Wear and abrasion are also important considerations in the use of the hose. Since the hose is relatively high priced, periodic replacement is a sizeable maintenance cost and should be considered in the purchase of this type system. If water is supplied by an open ditch, seepage losses may be high and field slopes must be such that these ditches are practical to use.

Continuous Move Boom. Figure 5.4 shows the operation of a boom sprinkler with a continuous move. A winch is anchored at one end of the field and an air-cooled gasoline engine winds up the cable which tows the sprinkler at a continuous rate along the lane through the field. The flexible hose supplies water to the sprinkler from the main line in the center of the field. For a lane length of 1,320 feet, about 600 feet of hose is required.

The distance between the lanes should be approximately equal to the diameter of the boom plus 70 percent of the difference between the wetted diameter and the boom diameter. Note, however, that the overlap problem between adjacent sprinkler patterns in the lane is no longer present. Thus, the total field distribution with the continuous move sprinkler is considerably better than with a set-type operation. The lane where the sprinkler and hose operate should be smooth and well maintained. The boom sprinkler, as it moves through the field, should not tilt one way or the other because of an uneven lane. This will cause an uneven water distribution pattern.

Design requirements are the same as shown for rotating boom.

Advantages and Limitations: Same as for rotating boom except rectangular fields are desirable and has high friction loss in flexible hose.

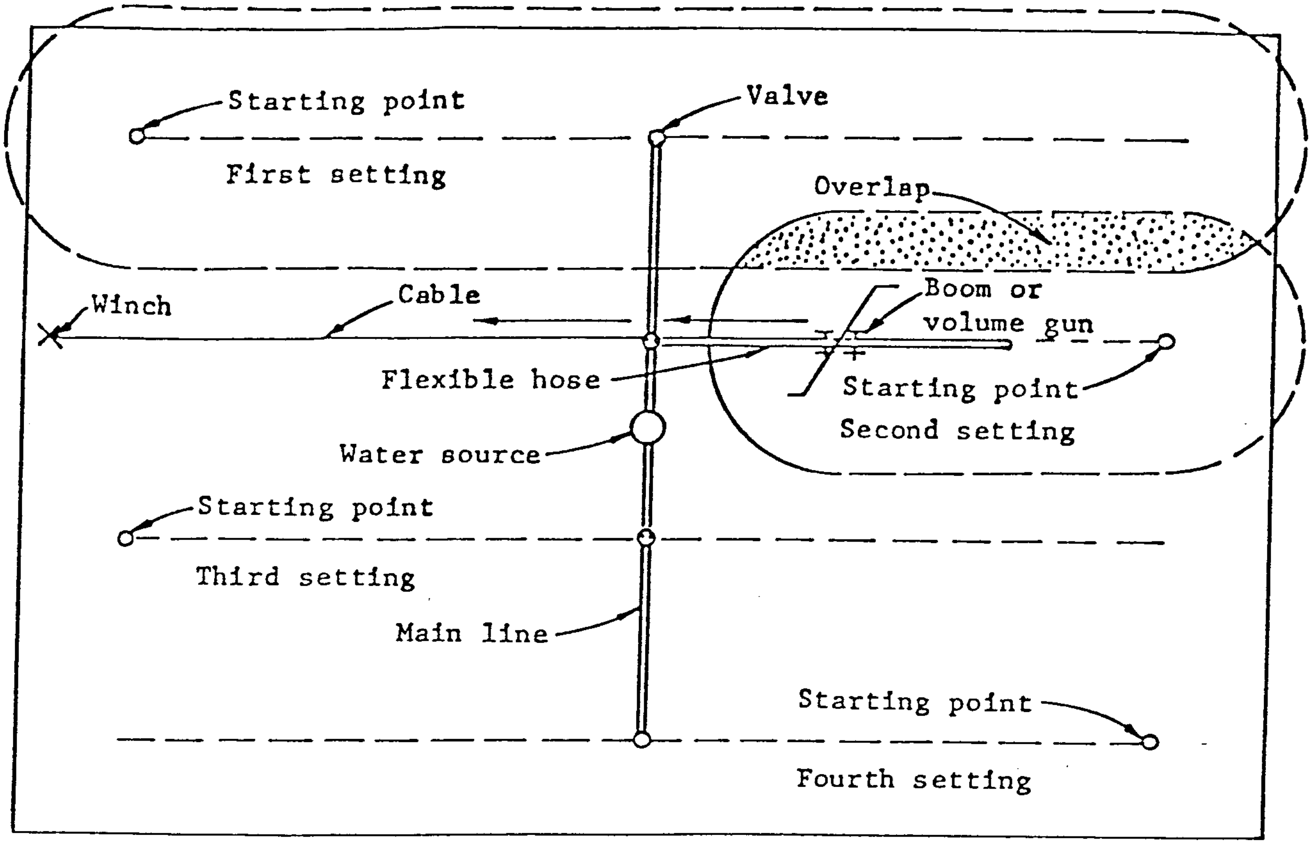


Figure 5.4, Continuous move boom or volume gun

Continuous Move Volume Gun. The same type continuous move operation is used with the volume gun as was explained for the boom.

The power to move the sprinkler may be supplied by self-propelled equipment or by a motor mounted on the sprinkler trailer which winds a cable on a drum. The cable is then anchored at the end of the field. Another method has the motor and winch anchored at the end of the field.

On some types of volume gun sprinklers using the continuous move principle, a sprinkler mechanism purposely does not water the lane area directly in front of its travel to keep a firm track for the sprinkler cart or trailer.

As with the continuous move boom sprinkler, the overlap pattern between individual sets along the lane is eliminated, meaning the distribution pattern is better with a continuous move sprinkler than with the same sprinkler set at selected intervals.

Advantages and Limitations: Same as for volume gun except rectangular fields are desirable and high friction loss in flexible hose.

Center-Pivot, Self-Propelled Sprinkler. This system consists of a single lateral mounted on wheels spaced on approximately 100 to 180-foot centers and supported by towers or bridge truss. Each of the towers has a device to provide power to the wheels. The type of power varies with the manufacturer. It can be provided by the water being pumped through the system, by hydraulic oil, by an electric motor on each tower, by compressed air, or by revolving jets.

The operation of the center-pivot, self-propelled sprinkler is shown in Figure 5.5. An anchored pivot point is located at the center of the field around which the entire system pivots.

The speed of rotation of the center-pivot system may vary from 12 hours to 120 hours per revolution. With the center-pivot, self-propelled system, the rate of water application is the same regardless of the speed of rotation. However, the faster the rotation speed, the less total water applied per rotation. An average rotation speed is approximately 60 to 72 hours per revolution. An average water application is approximately 1.0 to 1.5 inches.

The speed of the center-pivot, self-propelled sprinkler is usually controlled by the end tower, called the master tower. A system of alignment controls keep the other towers in line with the end tower.

With the center-pivot, self-propelled system, a circular or square field is required. On a quarter section, 160 acres, approximately 130 acres are under irrigation. About 7 acres in each corner of the field will not be irrigated.

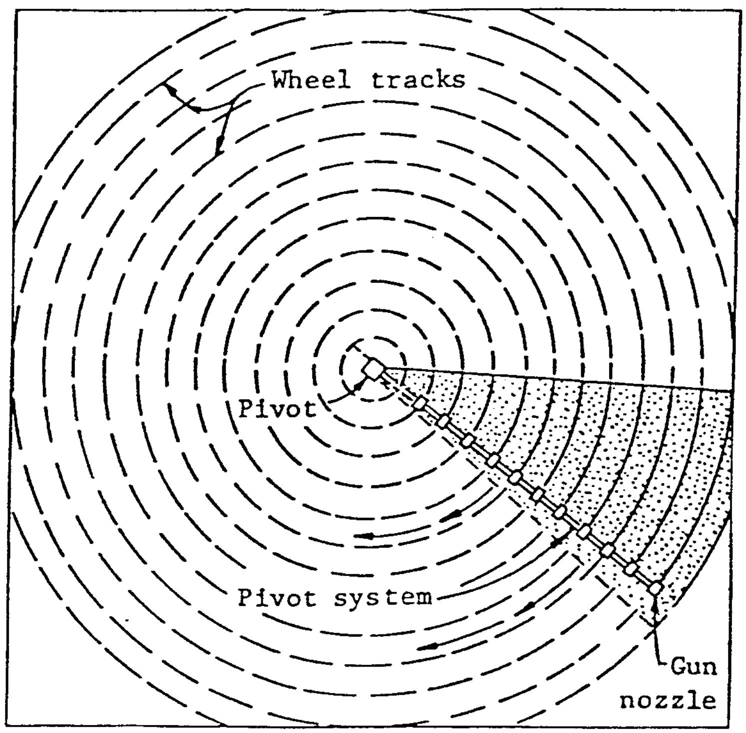


Figure 5.5 A center-pivot (Gun nozzle used in corners only)

To reduce the acreage not irrigated in the field corners most systems add a large volume sprinkler to the end of the system which is turned on at the corners. Another development has been the corner system which is a fold back tower section that automatically turns on and swings out at corners nearly eliminating non-irrigated acres. The corner systems all reduce the water to the rest of the system when they are turned on and tend to cause uneven irrigation.

Center pivot systems are fitted with either impact sprinklers or spray nozzles which are operated at pressures ranging from 30 p.s.i. to 75 p.s.i. Various configurations and options are available.

Advantages and Limitations: Requires circular or square fields with no obstructions. Application rate is high at outer end of line resulting in high application rate, especially using sprinklers with small wetted diameter which can cause excess runoff on low intake soils or steep topography. With repeated irrigations, there is a tendency for tower wheels to cut deep ruts in some soils. Center pivot systems require a minimum of operating labor. They can be used on all but the lowest intake soils and on sloping and irregular topography. Systems have high clearance suitable for tall crops.

Lateral Move, Self-Propelled Sprinkler: These systems are similar to center pivots but move laterally instead of circling. They apply water at equal rate along the system. Water must either be pumped from a parallel ditch or through a flexible drag hose. An onboard power source is required for movement.

Solid Set: With this system the main line and lateral lines remain in place during the growing season. In some systems the lines are buried with all sprinklers in permanent locations while others are laid out on the surface after planting and remain in place until harvest. Some systems are designed so all laterals operate fully at one time while others operate groups of laterals together sequencing the water over the field. See figure 5.6. Another system sequences sprinklers on the lateral lines in order automatically until complete coverage is obtained. See figure 5.7.

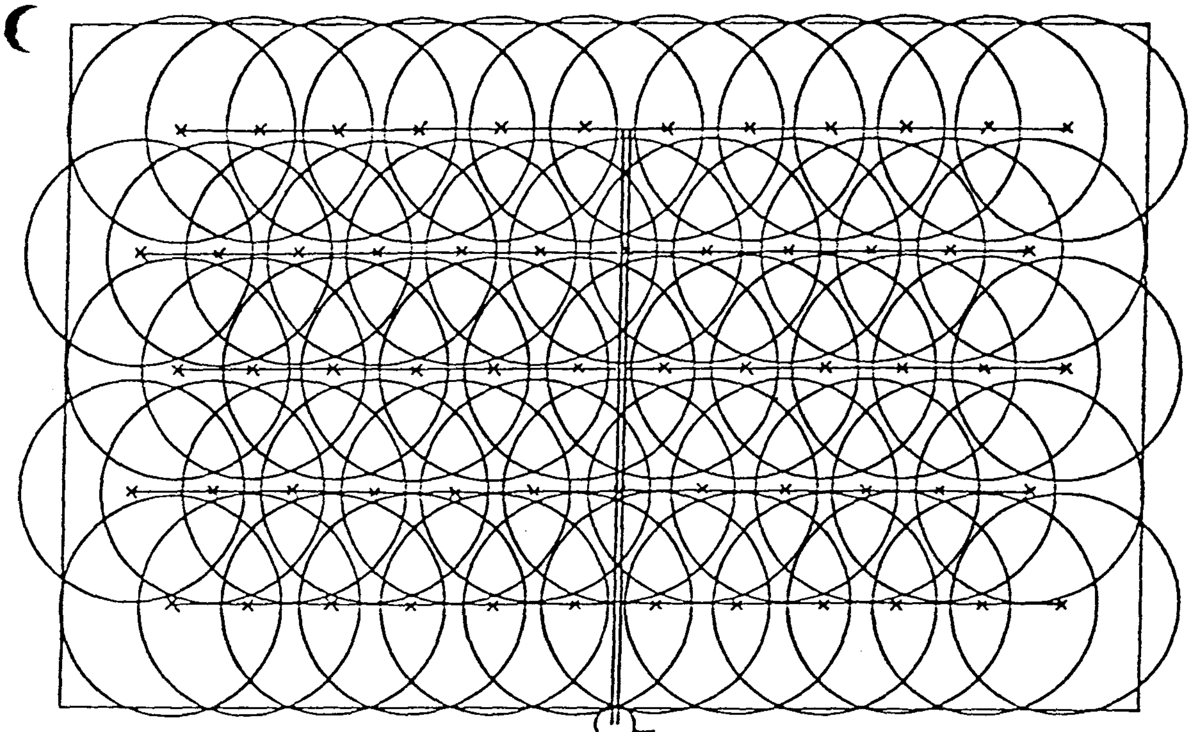


Figure 5.6, A solid set system

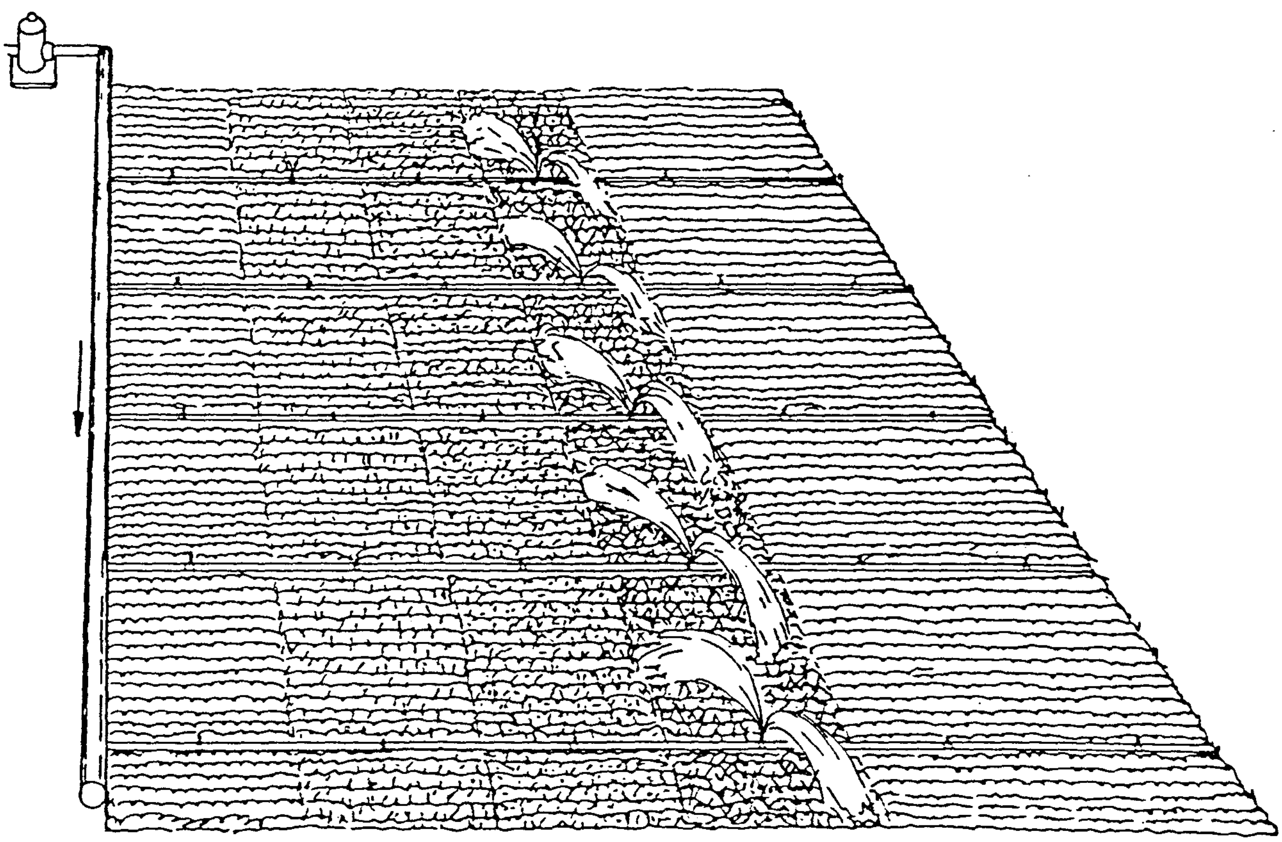


Figure 5.7, Sequencing solid set

DESIGN CONSIDERATIONS FOR A SPRINKLER SYSTEM USING LATERAL LINES OPERATING IN SETS

Sprinkler systems operating in sets require the moving of the laterals at specific intervals of time. In order to fit in with farm schedules, it is generally recommended that the time of sets be planned for 7-, 11-, or 23-hour periods of time which allows 1 hour per set for moving the lines and servicing the equipment.

The tables in this section have been prepared to provide guidance and these with the following criteria will provide data needed in recommending use of these systems.

(a) The allowable variation in lateral line pressure should not exceed ± 10 percent of the design pressure.

(b) For selection of most economical size, the loss in the main line should be 20 to 30 percent of the pressure at the pump.

(c) Sprinkler spacing pattern on the lateral line and later line spacing should be determined by wetted diameter of the sprinklers and the local wind conditions.

(d) Sprinkler nozzle size and pressure shall be selected to apply the required application rate at a recommended operating pressure.

The following example is not intended to show the complete design procedure but only as a guide in general determination of suitability of a specific system and approximate size requirements to guide the user in equipment selection. For more specific design criteria, refer to Chapter 11 of Section 15 of the National Engineering Handbook, Sprinkler Irrigation.

SPRINKLER IRRIGATION USING LATERALS OPERATING IN SETS

Problem: Select a sprinkler system to meet specific design requirements.

Given: Field E½ of NE¼ or dimensions of 1320' x 2640'.
Soil: Emrick on 2%.
Crop: Corn.
Well located at NW corner of SE¼ of NE¼. Well, pump and motor designed to supply 700 g.p.m. @ 65# pressure at pump.
Operator wants 11-hour settings (two settings per day). Prefers 40' x 60' spacing.

Solution:

(a) Determine allowable application rate:

Emrick is in Irrigation Group IVA, Chapter 2. Irrigation Group IVA for corn on 2% slope shows available water holding capacity for a 4.0' root zone as 9.2", thus 40% or 3.5" should be considered the net irrigation in planning the system. Therefore, consider a range from 3" to 4". The maximum application rate for Irrigation Group IVA soils on 2% slope is 0.90"/hr. for 3.0" and 0.80"/hr. for 4.0" net application (Table 5.2, Page 5-17).

(b) Determine sprinkler application efficiency:

Sprinkler application efficiency from Table 5.1 on Page 5-16 shows 70% for 3" or more net application when using an application rate of 0.3" to 0.5" per hour.

(c) Determine number of laterals to use:

Each lateral line would be 1,280' long to fit the field. Preferred sprinkler nozzle spacing is 40' as given. Then 1,320' @ 40' spacing would require 1,320 ÷ 40 = 33 nozzles per line. To distribute the 700 g.p.m. well capacity, the nozzles would have a capacity of:

$$\frac{700}{33} = 21.2 \text{ g.p.m. if only one lateral is used}$$

$$\frac{700}{2(33)} = 10.6 \text{ g.p.m. for two-line operations, and}$$

$$\frac{700}{3(33)} = 7.1 \text{ g.p.m. for three-line operations.}$$

From Table 5.3, Page 5-18, using the desired 40' x 60' spacing, the 21.2 g.p.m. would give an application rate of 0.85"/hr., 10.6 g.p.m. would give application rate of 0.42"/hr., and 7.1 g.p.m. would give rate of 0.28"/hr. For the desired 11-hour settings for operation of the system, the gross applications would then be 0.85 x 11 = 9.35" for one line, which is much too high, 0.42 x 11 = 4.62" for two lines in operation or 0.28 x 11 = 3.08" for three lines in operation. From Table 5.4, Page 5-19, using 70% efficiency, the net irrigation would be 3.2" or 2.2" respectively. A 3.2" net application in 11 hours is selected to most nearly meet the planned application of 3.5". Therefore, the two line operation is selected.

(d) Determine nozzle sizes and lateral spacing:

Assume that the size of the main selected will result in approximately 25% head loss in conveying water to the far end of the field. A head loss of 25% would be .25 x 65 p.s.i. = 16 p.s.i. Then pressures at entrance to the laterals would be 65 - 16 = 49 at distant lateral and 65 p.s.i. at lateral adjacent to pump. The average of these is (49 + 65) ÷ 2 = 57 p.s.i. at the entrance to the laterals.

If properly designed, the pressure at the lateral entrance should not be more than 10% above the average sprinkler pressure. Therefore, the average sprinkler pressure would be 57 p.s.i. less 10% or 52 p.s.i. Using a 52 p.s.i. pressure and a nozzle discharge of approximately 10.6 g.p.m. with Table 5.6, Page 5-20, a nozzle diameter of 7/32" is selected as the best choice with a discharge of 10.1 g.p.m. and a wetted diameter between 110' and 120'. Referring to Table 5.7, Page 5-21, the desired 40' x 60' spacing may be used.

(e) Determining lateral size:

The lateral lines will be 1,280' long with nozzles spaced 40' apart, for a total of 33 nozzles. These 33 nozzles at 10.1 g.p.m. each will require a capacity of 333 g.p.m. to the lateral. Allowable lateral line loss is 20% of the sprinkler operating pressure, 52 x .20 = 10.4 p.s.i. line loss. The allowable loss is converted to loss in feet per 100' by multiplying by 2.31 and dividing by the lateral length in multiples of 100, 10.4 x 2.31 ÷ 12.8 = 1.88'. A further correction for multiple outlets is applied using the factor found in Table 5.10, Page 5-23, 1.88' ÷ 0.36 = 5.21'. Comparing this 5.21' allowable loss with the losses for 333 g.p.m. shown in Table 5.9, Page 5-23, a selection of 5" diameter lateral is made.

(f) Determine size of main line:

With a two lateral operation, one lateral can start at the pump and one at the far end of the field and move in opposite directions. With this operation, the maximum loss is when one-half of the water is carried to the far end of the field or a distance of 1,280' (40' from fence line). A 5" main carrying 333 g.p.m. has friction loss of 2.36' per 100', using Table 5.9, Page 5-23. For 1,280' this is a head loss of 12.8 x 2.36' = 30.21'. Then 30.21' ÷ 2.31 = 13.08 p.s.i. head loss for the 5" main. Allowable loss is 20% to 30% of pump pressure or .20 x 65 p.s.i. to .30 x 65 p.s.i. or 13 p.s.i. to 20 p.s.i. Therefore, 5" size is most economical size for main line.

(g) Determine if system will meet crop needs:

With 333 g.p.m. per lateral and using two laterals, gives 666 g.p.m. = 6.66 x .223 = 1.48 ac. in./hr. Two 11-hour settings = 22 hours per day. Then 1.48 x 22 = 32.6 ac. in./day. Field is 80 acres.

Therefore, system supplies gross of

$$\frac{32.6}{30} = 0.41'' \text{ per day}$$

0.41" gross @ 70% efficiency = 0.41 x 0.70 = 0.29"/day net application. From Table 2.1, Page 2-3, design use rate for corn, Area II, and irrigation application of 3.0" to 3.5" is 0.23"/day. The system is adequate to meet consumptive use needs.

(h) Determine time to cover field:

Two lines 1,320' long with lateral moves of 60' per move and moved twice a day will cover 60' x 2 x 2 = 240'/day. Total distance to cover is 2,640'. Therefore, time to cover field is 2,640' ÷ 240 = 11 days.

TABLE 5.1
DESIGN FIELD EFFICIENCIES FOR SPRINKLER SYSTEMS

Systems Requiring Scheduled Moves			
Net Irrigation Application	Sprinkler Application Rate (Inches per Hour)		
	< 0.3	0.3 to 0.5	Over 0.5
< 2.0	.55	.60	.65
2.0 to 2.9	.60	.65	.70
3.0 or over	.65	.70	.75

Solid Set Systems			
Net Irrigation Application	Sprinkler Application Rate (Inches per Hour)		
	< 0.3	0.3 to 0.5	Over 0.5
< 1.0	.60	.65	.70
1.0 to 1.9	.65	.70	.75
2.0 or over	.70	.75	.80

TABLE 5.2

FOR LATERAL LINES AND SYSTEMS OPERATING IN SET POSITIONS
MAXIMUM SPRINKLER APPLICATION RATES (IN/HR)
CROPS WITH COVER

For Bare Ground or Row Crops Use 2/3 of Maximum Value

IRRIG. GROUP	LAND SLOPES	NET APPLICATION 0.5"	1.0"	1.5"	2.0"	3.0"	4.0"	5.0"
(0.3) IIA, IIB, IIC	Under 2%	2.00	.90	.50	.45	.35	.30	.25
	2-5	1.60	.60	.45	.40	.30	.25	.20
	Over 5	1.50	.50	.40	.35	.20	.20	--
(0.5) IIIA, IIIB, IIIC, IIID	Under 2%	2.00	1.50	.85	.85	.65	.55	.50
	2-5	2.00	1.00	.75	.70	.50	.45	.40
	Over 5	1.80	.90	.70	.60	.40	.35	.30
(1.0) IVA, IVB, VA, VB, VIA, VIB, VIC	Under 2%	2.00	2.00	1.70	1.70	1.35	1.20	1.10
	2-5	2.00	2.00	1.50	1.50	1.10	.95	.85
	Over 5	2.00	2.00	1.40	1.40	.85	.75	.65
(1.5) VIIA, VIIB	Under 2%			2.00	2.00	2.00	1.80	1.65
	2-5			2.00	1.80	1.60	1.45	1.30
	Over 5			2.00	1.60	1.40	1.20	1.00
(2.0) VIIIA, VIIIB	Under 2%				2.00	2.00	2.00	2.00
	2-5				2.00	2.00	1.90	1.85
	Over 5				2.00	2.00	1.45	1.35
(3.0&4.0) IX, X		2.00 considered as highest practicable rate for design or operation of system.						

TABLE 5.3
TABLE OF PRECIPITATION - INCHES PER HOUR

Spacing (feet)	Gallons per minute from each sprinkler														
	2	3	4	5	6	7	8	9	10	11	12	15	18	20	25
30x30	.21	.32	.43												
30x40	.16	.24	.32	.40	.48	.52	.64	.72							
30x50			.25	.32	.38	.44	.51	.57	.64	.70	.76				
30x60				.27	.32	.37	.43	.48	.53	.58	.64	.80			
40x40		.18	.24	.30	.36	.42	.48	.54							
40x50				.24	.29	.33	.38	.43	.48	.53	.58				
40x60				.20	.24	.28	.32	.36	.40	.44	.48	.60	.72	.80	
50x50					.23	.27	.31	.35							
50x60					.19	.22	.26	.29	.32	.35	.39	.48	.58	.64	
50x70						.19	.22	.25	.28	.30	.33	.41	.49	.55	.69
60x60							.21	.24	.27	.29	.32	.40	.48	.53	.67
60x70								.20	.23	.25	.27	.34	.41	.46	.57
60x80									.20	.22	.24	.30	.36	.40	.50

TABLE 5.4

GROSS IRRIGATION APPLICATION

Net Irrig. Depth	Gross Irrigation Depth for Design Efficiency					
	80	75	70	65	60	55
1.6	2.00	2.13	2.28	2.46	2.67	2.91
1.8	2.25	2.40	2.57	2.77	3.00	3.27
2.0	2.50	2.66	2.86	3.08	3.33	3.64
2.2	2.75	2.93	3.14	3.39	3.67	4.00
2.4	3.00	3.20	3.43	3.70	4.00	4.37
2.6	3.25	3.46	3.71	4.01	4.33	4.73
2.8	3.50	3.73	4.00	4.32	4.67	5.09
3.0	3.75	4.00	4.28	4.63	5.00	5.45
3.2	4.00	4.26	4.57	4.93	5.33	5.82
3.4	4.25	4.53	4.86	5.24	5.67	6.18
3.6	4.50	4.79	5.14	5.55	6.00	6.55
3.8	4.75	5.06	5.43	5.86	6.33	6.91
4.0	5.00	5.33	5.71	6.17	6.67	7.28
4.2	5.25	5.60	6.00	6.47	7.00	7.64
4.4	5.50	5.86	6.28	6.78	7.33	8.00
4.6	5.75	6.12	6.57	7.09	7.67	8.36
4.8	6.00	6.39	6.86	7.40	8.00	8.73
5.0	6.25	6.65	7.14	7.71	8.33	9.10
5.2	6.50	6.92	7.43	8.02	8.67	9.46
5.4	6.75	7.18	7.71	8.33	9.00	9.82
5.6	7.00	7.45	8.00	8.63	9.33	10.18

TABLE 5.5

SPRINKLER APPLICATION RATE

Appl. Rate In./Hr.	Application Per Lateral Set		
	7 Hr.	11 Hr.	23 Hr.
.18	1.26	1.98	4.14
.20	1.40	2.20	4.60
.22	1.54	2.42	5.06
.24	1.68	2.64	5.52
.26	1.82	2.86	5.98
.28	1.96	3.08	6.44
.30	2.10	3.30	6.90
.32	2.24	3.52	7.36
.34	2.38	3.74	7.82
.36	2.52	3.96	8.28
.38	2.66	4.18	8.74
.40	2.80	4.40	9.20
.42	2.94	4.62	9.66
.44	3.08	4.84	10.12
.46	3.22	5.06	-
.48	3.36	5.28	-
.50	3.50	5.50	-
.52	3.64	5.72	-
.54	3.78	5.94	-
.56	3.92	6.16	-
.58	4.06	6.38	-
.60	4.20	4.60	-
.62	4.34	6.82	-
.64	4.48	7.04	-
.66	4.62	7.26	-
.68	4.76	7.48	-
.70	4.80	7.70	-
.75	5.25	8.25	-
.80	5.60	8.80	-

TABLE 5.6

NOZZLE DISCHARGE, GPM AND

AVERAGE WETTED DIAMETER 1/
FOR SPRINKLER NOZZLES

Nozzle Diameter (Inches)	Pressure at Nozzle - psi 45	50	55	60	65	70	75	80	85	90
1/16	.76	.80	.85	60' .88						
5/64	1.2	1.2	1.3	1.3						
3/32	1.7	1.8	1.9	2.0	2.1	70' 2.1	2.2	2.3		
7/64	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	80'	
1/8	3.0	3.1	3.3	3.4	3.6	3.7	3.9	4.0	90'	
9/64	3.8	4.0	4.2	4.3	4.5	4.7	4.9	5.0	100'	
5/32	4.7	5.0	5.2	5.4	5.7	5.9	6.2	6.3		
11/64	5.7	6.0	6.3	6.6	6.8	7.1	7.3	7.6	110'	
3/16	6.8	7.2	7.5	7.8	8.2	8.5	8.8	9.1	120'	
13/64	8.1	8.5	8.9	9.2	9.5	9.8	10.2	10.5		
7/32	9.4	9.9	10.2	10.7	11.0	11.5	12.0	12.4	130'	
1/4	12.2	12.9	13.6	14.2	14.8	15.4	16.0	16.5	140'	
9/32	15.5	16.3	17.2	18.0	18.8	19.5	20.3	20.9		150'
5/16	18.9	20.0	21.0	22.0	23.0	23.9	24.8	25.7		160'
11/32	22.5	23.8	25.0	26.0	26.9	28.1	29.2	30.4	31.5	170' 32.7
3/8	26.0	27.5	29.1	30.6	32.0	33.3	34.5	35.7	37.0	38.3
13/32		32.2	34.3	36.5	38.1	38.9	40.3	41.8	43.2	44.6
7/16	160'	38.6	40.4	42.2	43.9	45.1	46.8	48.4	50.0	51.5
15/32		170'		48.0	50.0	51.4	53.3	55.1	56.9	58.5
1/2			180'		190'	57.5	59.6	61.6	63.5 200'	65.3

1/ Approximate diameter of coverage. For sprinklers with more than one nozzle, wetted diameter is that of the larger nozzle.

TABLE 5.7

MAXIMUM SPACING FOR SPRINKLERS 1/

Wetted Diameters for Nozzle 2/	Sprinkler Spacing: Wind to 10 m.p.h. $S_l \times S_m$ 3/	Sprinkler Spacing: Wind over 10 m.p.h. $S_l \times S_m$ 3/
60	30 x 40	20 x 30
80	30 x 50	30 x 40
100	40 x 60	30 x 50
120	50 x 60	40 x 60

1/ Spacing is based on using 40% of the wetted diameter of the sprinkler nozzle between sprinklers and 60% between laterals for average wind conditions of under 10 m.p.h. The spacing for winds averaging over 10 m.p.h. is based on a 30% of wetted diameter of the sprinkler nozzle between sprinklers and 50% between laterals.

2/ The approximate diameter of sprinkler nozzle coverage at the selected operating pressure.

3/ S_l refers to sprinkler spacing along the lateral line. S_m refers to lateral spacing along the main line.

TABLE 5.8
PERFORMANCE DATA OF TYPICAL SPRINKLERS

PSI	RB 14 V								B 170 G					
	Nozzle Size								Nozzle Size					
	1/16"		5/64"		3/32"		7/64"		7/64"		1/8"		9/64"	
	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM
45	62	.76	66	1.2	71	1.7	75	2.3	71	2.3	74	3.0	77	3.8
50	63	.80	67	1.2	72	1.8	76	2.4	72	2.4	76	3.1	78	4.0
55	64	.85	68	1.3	73	1.9	77	2.6	73	2.5	77	3.3	79	4.2
60	65	.88	69	1.3	74	2.0	77	2.7	74	2.6	78	3.4	80	4.3
65	--	--	--	--	--	--	--	--	75	2.7	79	3.6	81	4.5
70	--	--	--	--	--	--	--	--	76	2.8	80	3.7	82	4.7

PSI	RB 20						B 180 GE							
	Nozzle Size						Nozzle Size							
	9/64"		5/32"		11/64"		5/32"		11/64"		3/16"		13/64"	
	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM
45	80	3.8	81	4.7	82	5.6	--	--	--	--	--	--	--	--
50	81	4.0	82	4.9	83	5.9	98*	5.0	100*	6.0	106*	7.2	107*	8.5
55	81	4.2	82	5.2	83	6.3	100	5.2	102	6.3	108*	7.5	108*	8.9
60	81	4.4	82	5.4	83	6.5	101	5.4	103	6.6	109	7.8	110*	9.2
65	81	4.6	82	5.7	--	--	102	5.7	104	6.8	110	8.2	112	9.5
70	81	4.8	82	5.9	--	--	103	5.9	106	7.1	111	8.5	114	9.8
75	--	--	--	--	--	--	104	6.2	108	7.3	112	8.8	116	10.2
80	--	--	--	--	--	--	105	6.3	110	7.6	113	9.1	118	10.5

PSI	RB 14070 W						RB 70 EW							
	Nozzle Size						Nozzle Size							
	11/64"		3/16"		13/64"		7/32"		1/4"		9/32"		5/16"	
	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM
50	106*	6.0	109*	7.2	113*	8.5	125	9.9	134	12.9	138*	16.3	140*	20.0
55	107*	6.3	110*	7.5	115*	8.9	127	10.4	136	13.6	141	17.2	144*	21.0
60	108	6.6	111	7.8	116	9.2	129	10.9	139	14.2	144	18.0	148	22.0
65	109	6.8	112	8.2	117	9.5	131	11.4	142	14.8	147	18.8	152	23.0
70	110	7.1	113	8.5	118	9.8	134	11.8	145	15.4	150	19.5	155	23.9
75	111	7.3	114	8.8	119	10.2	137	12.2	148	16.0	153	20.3	158	24.8

PSI	RB 80 EW-TNT													
	Nozzle Size													
	11/32"		3/8"		13/32"		7/16"		15/32"		1/2"		17/32"	
	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM
70	162	28.1	166	33.3	172	38.9	178*	45.1	183*	51.4	189*	57.5	196*	63.5
75	164	29.2	169	34.5	175	40.3	181	46.8	186	53.3	192	59.6	199*	65.8
80	167	30.4	172	35.7	178	41.8	184	48.4	189	55.1	195	61.6	202	68.1
85	170	31.5	175	37.0	181	43.2	187	50.0	192	56.9	198	63.5	205	70.3
90	173	32.7	178	38.3	184	44.6	190	51.5	195	58.5	201	65.3	208	72.4
95	175	33.9	180	39.5	186	46.0	192	53.0	197	60.0	203	67.1	210	74.4

* Not Recommended

TABLE 5.9
FRICTION LOSS IN FEET PER 100 FEET IN LATERAL LINES OF
PORTABLE ALUMINUM PIPE WITH COUPLINGS

(Based on Scobey's formula and 30-foot pipe lengths)[1/]

Flow (gpm)	2-inch[2/] K_s = .34	3-inch[2/] K_s = .33	4-inch[2/] K_s = .32	5-inch[2/] K_s = .32	6-inch[2/] K_s = .32
100	25.4	3.20	0.738	0.244	0.099
120		4.54	1.04	.339	.140
140		6.09	1.40	.454	.188
160		7.85	1.80	.590	.242
180		9.82	2.26	.733	.302
200		12.0	2.76	.896	.370
220		14.4	3.30	1.07	.443
240		16.9	3.90	1.26	.522
260		19.7	4.54	1.47	.608
280		22.8	5.22	1.70	.700
300		25.9	5.96	1.93	.798
320		29.3	6.74	2.18	.904
340		32.8	7.56	2.45	1.02
360		36.6	8.40	2.74	1.13
380		40.6	9.36	3.03	1.26
400		44.7	10.3	3.34	1.38
420			11.3	3.66	1.51
440			12.3	4.00	1.66
460			13.4	4.35	1.80
480			14.6	4.72	1.95
500			15.8	5.10	2.12
550			18.9	6.12	2.52
600			22.2	7.22	2.98
650			25.9	8.40	3.46
700			29.8	9.68	3.99
750			33.8	11.0	4.54
800				12.5	5.15
850				14.0	5.78
900				15.6	6.44

1/ For 20-foot pipe lengths, increase values in the table by 7.0 percent. For 40-foot lengths, decrease values by 3.0%.

2/ Outside diameter.

TABLE 5.10
Correction Factor for Multiple Outlets

Outlets (Number)	Value of F	Outlets (Number)	Value of F
1	1.000	16	0.377
2	.634	17	.375
3	.528	18	.373
4	.480	19	.372
5	.451	20	.370
6	.433	21	.369
7	.419	22	.368
8	.410	23	.367
9	.402	24	.366
10	.396	25	.365
11	.392	26	.364
12	.388	27	.364
13	.384	28	.363
14	.381	29	.363
15	.379	30	.362

DESIGN CONSIDERATIONS FOR CONTINUOUS MOVE SPRINKLERS

General

Continuous move sprinklers vary in characteristics and design from intermittent move sprinklers. Different principles are involved in regard to application rates, total application per irrigation, pattern uniformity, etc. and in the design hydraulics involved.

Several types of sprinklers are in the continuous move category. These are: continuous move volume gun, continuous move boom, continuous move lateral (rectangular pattern) and center pivot. Following are some guidelines for use in system design and performance checks.

Two items of major concern in the design of these systems are: (1) The system must meet the water requirements of the crop during the peak use season, and (2) the rate of application must be within the allowable soil intake rate.

Maximum allowable application rates

Generally continuous move sprinklers apply smaller applications of water per irrigation and in shorter periods of time. As a result of these light applications, the intake rate of the soil remains in the initial stage throughout the entire irrigation period. Averaging the rate over this short period gives us a higher allowable intake rate than for intermittent move sprinklers which apply larger amounts of water over longer periods of time. Also, some allowance can be given for storage of water on the ground surface to be infiltrated into the soil after the water application is completed. Maximum application rates are given in Table 5.2, Page 5-17.

The actual application rate of a planned system is determined by dividing the gross amount of water applied per irrigation by the time it takes to apply it. Following is a brief discussion of procedures to use for guidance in recommending suitability of these types of systems.

A. Center-Pivot Systems

Center-pivot systems are unique in that the rate of speed and also the rate of water application must increase as the distance from the pivot point increases. Therefore, there is no one application rate for these systems.

We can check the operating characteristics of this type system by determining the gross application and application rate at a point toward the outside end of the lateral. If the system is properly designed, the application will be nearly uniform over the remainder of the lateral, and the application rate will decrease toward the pivot and therefore be satisfactory if the outer end application rate is within the soil intake limitations.

The following procedure can be followed to check the system:

(1) Determine if the system has the capacity to meet the design consumptive use. The required gross system capacity can be computed by the following formula:

$$\text{Required gross system capacity inches/day} = \frac{\text{Design period consumptive use inches/day}}{\text{Efficiency in \%}}$$

Where: Design period consumptive use of the crop for the proper climatic area is selected from Figure 3.1 and Table 3.3 beginning on Page 3-22. Efficiency is the recommended design efficiency from Table 5.11 on Page 5-27.

The actual gross capacity of the system in inches/day can be selected from Table 5.14, Page 5-30, for the length of lateral and gallons per minute capacity of the system. This actual capacity must equal the required capacity computed above, if the system is to meet the design consumptive use of the crop.

An alternate method for determining if the sprinkler system has the capacity to meet the design consumptive use is with the monograph in Table 5.13 on Page 5-29.

(2) Determine whether the application rate is compatible with the allowable application rates as listed in Table 5.12, Page 5-28.

The following is an example of this computation:

Given:

Lateral length - 1300'
Capacity of System = 800 g.p.m.
Nozzle pressure at end of line = 60 p.s.i.
Nozzle sizes last 100' of line = 1/4" X 13/32"
Planned application approximately 1" per revolution

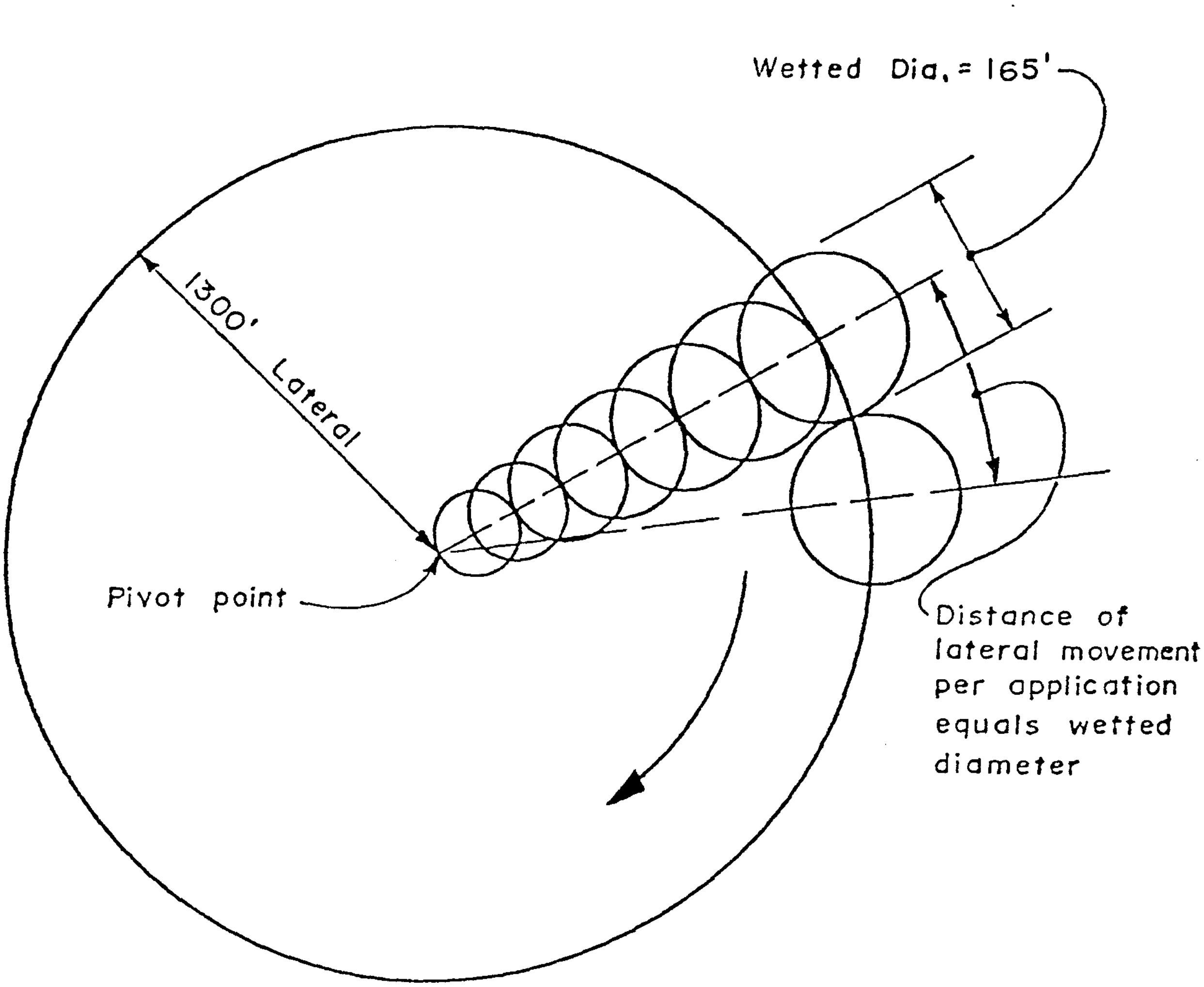


FIGURE 3--PLAN OF PIVOTAL SYSTEM

a. Determine required time per revolution from Table 5.14, Page 5-30, to apply the required 1" = 68.6 hrs.

b. Determine velocity of outside end of line from

$$\text{Velocity in feet/hour} = \frac{\text{Outside Circumference}}{\text{Time per Rev.}}$$

$$= \frac{1300 \times 2 \times 3.14}{68.6}$$

$$= 119'/\text{hour}$$

c. Determine diameter of throw of the 13/32" x 1/4" nozzle at the 60 p.s.i. pressure from Table 5.6, Page 5-20 = 165'.

d. Determine time of application as the time it takes the sprinkler to move past one point from

$$\text{Time of application (hrs.)} = \frac{\text{Diameter of throw}}{\text{Velocity of travel}}$$

$$= \frac{165}{119} = 1.39 \text{ hr.}$$

e. Determine the average application rate from the formula

$$\text{Average application rate } \frac{\text{inches}}{\text{hour}} = \frac{\text{Gross application (in.)}}{\text{Time of application (hrs.)}}$$

$$= \frac{1.0 \text{ inches}}{1.39 \text{ hours}} = .72'' \text{ per hour}$$

f. Since the water application pattern is parabolic, i. e., water is applied much faster as the sprinkler head passes directly over a point, the maximum rate is approximately 1.5 times the average or

Maximum rate = 1.5 x 0.72 = 1.08" per hour.

This actual maximum application rate must be less than the maximum allowable application rate for the soil, slope and depth of application as given in Table 5.12, Page 5-28.

TABLE 5.11
ESTIMATED DESIGN EFFICIENCIES FOR
CONTINUOUS MOVE SPRINKLER IRRIGATION

Net Irrigation Application Inches	Efficiency in %
Less than 0.5	50
0.5	60
1.0	70
1.5 - 2.0	75
Greater than 2.0	70

Table 5.12
Maximum Continuous Move Sprinkler Application Rates

For bare ground or crops with very limited soil cover use 2/3 of the maximum application value.

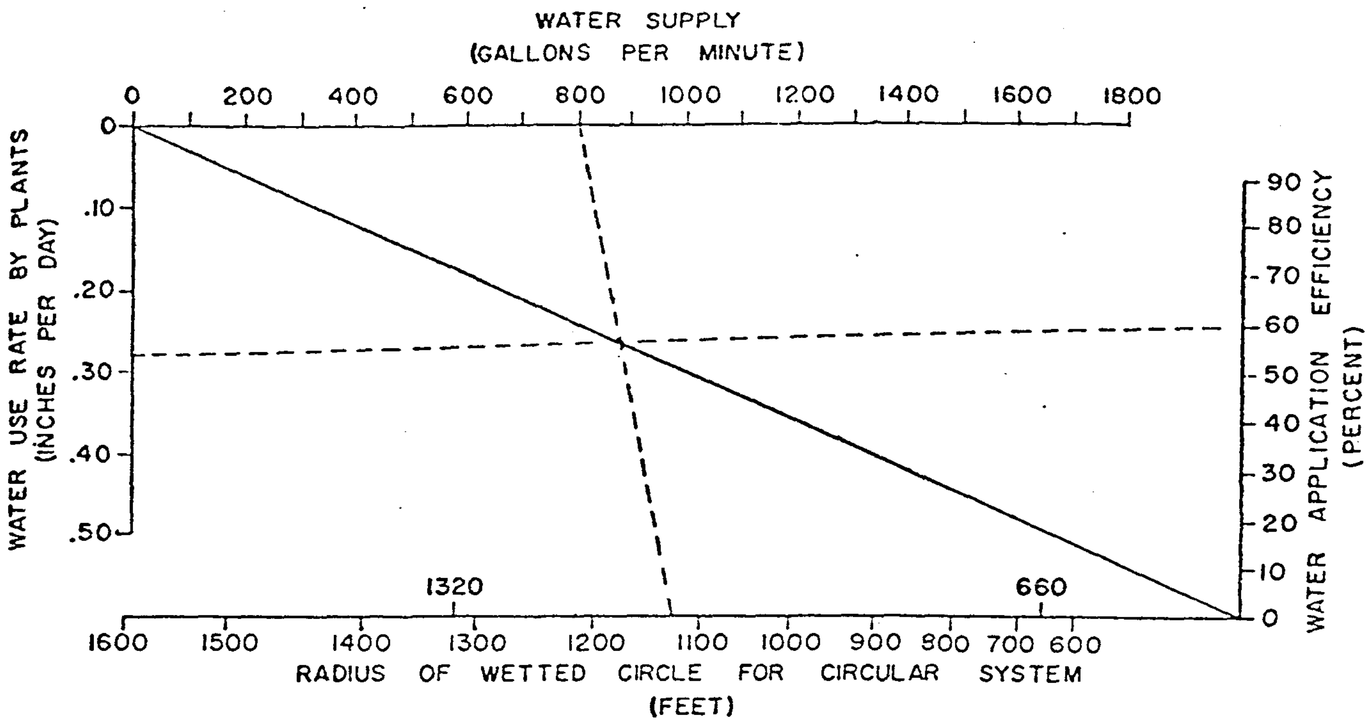
Net Applic	Slope Group	Surface Storage	Soil Intake Amt.	Soil Groups for Irrigation													
				II A,B,C		III A,B,C,D		IV A,B, V A,B & VI A,B,C		VII A,B		VIII A,B		IX		X	
				Min. Applic Time	Max. Applic Rate	Min. Applic Time	Max. Applic Rate	Min. Applic Time	Max. Applic Rate	Min. Applic Time	Max. Applic Rate	Min. Applic Time	Max. Applic Rate	Min. Applic Time	Max. Applic Rate	Min. Applic Time	Max. Applic Rate
inches	percent	inches	inches	min.	in/hr	min.	in/hr	min	in/hr	min	in/hr	min	in/hr	min	in/hr		
0.5	0-1	0.5	0	6	10.0	6	10.0	6	10.0	6	10.0	6	10.0	6	10.0		
0.5	1-3	0.3	0.2	7	8.0	6	10.0	6	10.0	6	10.0	6	10.0	6	10.0		
0.5	3-5	0.1	0.4	9	6.5	6	10.0	6	10.0	6	10.0	6	10.0	6	10.0		
0.5	>5	0	0.5	13	4.0	10	6.0	6	10.0	6	10.0	6	10.0	6	10.0		
1.0	0-1	0.5	0.5	14	8.0	11	10.0	11	10.0	11	10.0	11	10.0	11	10.0		
1.0	1-3	0.3	0.7	30	4.0	21	5.5	11	10.0	11	10.0	11	10.0	11	10.0		
1.0	3-5	0.1	0.9	55	2.0	33	3.5	17	7.0	14	8.0	11	10.0	11	10.0		
1.0	>5	0	1.0	64	1.5	38	3.0	19	6.0	17	7.0	14	8.0	11	10.0		
1.5	0-1	0.5	1.0	64	2.5	38	4.5	21	8.0	17	10.0	17	10.0	17	10.0		
1.5	1-3	0.3	1.2	80	2.0	60	3.0	30	5.5	21	8.0	17	10.0	17	10.0		
1.5	3-5	0.1	1.4	140	1.5	75	2.5	35	4.5	25	7.0	21	8.0	17	10.0		
1.5	>5	0	1.5	162	1.0	80	2.0	42	4.0	30	5.5	25	7.0	17	10.0		

Maximum application rate is 1.5 times the average application rate.

The minimum application times were based on accumulated intake vs time curves which represent the intake range of soils within the irrigation soil groups.

Maximum application rate was limited to the highest calculated rate for a 1300 ft. system with a 0.40 in/day capacity and a 20 ft. throw diameter.

TABLE 5.13
Center Pivot Water Supply Nomograph



The nomograph above, designed by the Cooperative Extension Service of Oklahoma State University, can be used to calculate water supply requirements for self-propelled, center pivot sprinkler systems. Its use is explained by the following examples:

Example 1:

Given: Water supply, 800 gpm; plant water use rate, 0.28" per day; water application efficiency, 60%. What is the radius of the circle that this system will adequately irrigate?

Solution: Locate 0.28" on the "Water Use Rate" scale and 60 on the application efficiency scale. Connect the two points by using a straightedge and note the point of intersection on the solid diagonal line. Locate 800 gpm on the upper scale labeled "Water Supply"; connect this point with the point located on the diagonal line and project this line to the lower scale labeled "Radius of Wetted Circle." This point reads slightly more than 1,100' - the maximum radius of the wetted circle that 800 gpm will properly irrigate.

Example 2:

Given: Desired radius of wetted circle, 1,320'; water use rate 0.20" per day; application efficiency, 60%. What is the required water supply?

Solution: Locate 1320 on the lower scale, then draw a line from this point through the intersection point on the diagonal and extend it on to the upper scale labeled "Water Supply." The point on the upper scale is near 800 gpm. A water supply of 800 gpm is required to adequately irrigate a circle this size under the given conditions. It is obvious that an increase in water application efficiency will reduce the total water requirements.

TABLE 5.14

TIME REQUIRED TO APPLY 1" GROSS APPLICATION
AND GROSS CAPACITY OF CENTER PIVOT SYSTEMS

Total Lateral Length	Area* Covered (acres)	Hours Per 1" Application (Col. 1) Gross Capacity in in./day (Col. 2)									
		400 g.p.m.		600 g.p.m.		800 g.p.m.		1000 g.p.m.		1200 g.p.m.	
		hrs/ in.	in./ day	hrs/ in.	in./ day	hrs/ in.	in./ day	hrs/ in.	in./ day	hrs/ in.	in./ day
600	26	29.2	.82	19.5	1.23	14.6	1.65	11.7	2.06	9.8	2.44
650	30.5	34.4	.70	23.0	1.04	17.2	1.4	13.7	1.75	11.4	2.10
700	35.3	39.7	.62	26.4	.91	19.8	1.2	15.9	1.51	13.2	1.82
750	40.6	45.6	.52	30.4	.79	22.9	1.05	18.2	1.32	15.2	1.58
800	46.2	52.0	.46	34.6	.69	26.0	.92	20.8	1.15	17.3	1.39
900	58.4	66.1	.36	44.0	.54	32.8	.73	26.3	.91	21.9	1.09
950	65.0	73.0	.33	48.7	.49	36.6	.65	29.3	.82	24.3	.99
1000	72.2	81.2	.29	54.2	.44	40.6	.59	32.5	.74	27.1	.89
1050	79.5	89.2	.27	59.5	.40	44.8	.53	35.8	.67	29.8	.81
1100	87.4	98.3	.24	65.5	.37	49.2	.49	39.4	.61	32.8	.73
1150	95.3	107	.22	71.5	.33	53.6	.45	42.9	.56	35.7	.67
1200	104.0	117	.20	78.0	.31	58.5	.41	46.8	.51	39.0	.61
1250	112.6	126	.19	84	.29	63.4	.38	50.7	.47	42.2	.57
1300	121.9	137	.17	91.5	.26	68.6	.35	54.9	.44	45.6	.52
1350	131.4	148	.16	98.6	.25	73.9	.33	59.1	.41	49.3	.49
1400	141.3	159	.15	106	.23	79.5	.30	63.6	.38	53.0	.45
1450	151.6	170	.14	113	.21	85.5	.28	68.3	.35	56.7	.42
1500	162.3	182	.13	122	.20	91.2	.26	73.0	.33	60.7	.40
1550	173.2	194	.12	130	.18	97.5	.25	78.0	.31	65.0	.37
1600	184.7	203	.11	138	.17	104	.23	83.0	.29	69.2	.35

*Without gun sprinkler. For added area covered by a gun sprinkler, see Table 5.15, page 5-31.

TABLE 5.15

CENTER-PIVOT IRRIGATION SYSTEMS

% of water applied in last 100' 1/	Total system length (in feet) 2/	Total area of square field twice length of system (in acres)	Area Covered in Acres		
			Without end gun	With gun 3/ sprinkler used only in corners	With gun sprinkler used on entire circle 3/
30.6	600	33.1	26.0	30.8	35.3
28.4	650	38.8	30.5	36.0	40.6
26.5	700	45.0	35.3	41.3	46.1
24.8	750	51.8	40.6	47.2	52.1
23.4	800	58.8	46.1	53.3	58.4
22.1	850	66.3	52.1	59.8	65.0
21.0	900	74.5	58.4	66.7	72.2
20.0	950	82.9	65.0	74.0	79.5
19.0	1000	91.8	72.2	81.7	87.4
18.1	1050	101.3	79.5	89.5	95.3
17.3	1100	111.0	87.4	98.0	104.0
16.6	1150	121.3	95.3	106.6	112.6
16.0	1200	132.2	104.0	115.7	121.9
15.4	1250	143.3	112.6	123.8	131.4
14.8	1300	155.0	121.9	134.0	141.3
14.3	1350	167.3	131.4	145.0	151.6
13.8	1400	179.8	141.3	155.2	162.0
13.3	1450	193.0	151.6	166.5	173.2
12.9	1500	206.0	162.0	177.7	184.7

1/ Less volume of end gun when used.

2/ Generally outside drive wheel approximately 50' from end.

3/ Based on 100' gun coverage.

EXAMPLE: System is 900' long. Then 21% of water is applied in last 100'; 66.7 acres are covered with gun used in corners only.

B. Continuous Move Volume Gun Sprinklers

As the name suggests, these sprinklers move as they apply the irrigation water. They irrigate by sets which are normally no more than 1,320 feet in length with travel lane widths equal to some percentage of the sprinkler's diameter of throw. They should be designed to apply an adequate irrigation while moving over the set in a convenient time period. Wind distortion, puddling, and runoff are the major disadvantages of these sprinklers. To reduce these effects, proper lane spacing, trajectory angle and operating pressure must be determined for the wind and soil conditions.

The following procedure can be used to check a system:

(1) Determine the system capacity required.

$$\text{Required gross capacity (in./day)} = \frac{\text{Design period consumptive use (in./day)}}{\text{System efficiency}}$$

Where: The design period consumptive use is selected from Tables 3.3 on Pages 3-22 through 3-24 for the crop, proper climatic area and net irrigation selected on the basis of Irrigation Group. The system efficiency is selected from Table 5.11 on Page 5-27. Convert the gross capacity in in./day to a sprinkler rate in gallons per minute.

Sprinkler rate (g.p.m.) = Gross capacity (in./day) X acres X 18.9

(2) Determine the maximum application rate (in./hr.) for the Irrigation Group, slope and selected net irrigation application from Table 5.12 on Page 5-28.

(3) Determine the system design limits. Divide the maximum application rate by 1.5 to arrive at the average application rate (in./hr.). Using Table 5.16 on Page 5-33, select a nozzle size and trajectory compatible with the average application rate and wind conditions. With the nozzle size and sprinkler rate, select from Tables 5.17 or 5.18 on Pages 5-34 and 5-35 the operating pressure and sprinkler diameter. Select a travel lane spacing for the design wind condition and sprinkler diameter with Table 5.20 on Page 5-36.

Using the sprinkler rate and lane spacing from Table 5.21 or the formula shown on Page 5-37, select a travel speed that most nearly fits the gross application depth of water desired. An operation system can then be selected using Table 5.19 on Page 5-36 and minor adjustments made in lane spacing to fit the set time selected.

TABLE 5.16

AVERAGE APPLICATION RATES OF
LARGE FULL CIRCLE SPRINKLERS 1/

Ring Nozzles			Taper Bore Nozzles		
Nozzle Size In.	Trajectory Angle Degrees	Appl. Rate In./Hr.	Nozzle Size In.	Trajectory Angle Degrees	Appl. Rate In./Hr.
1 1/4	27	0.30	1.05	27	0.28
	21	0.33		21	0.31
1 3/8	27	0.33	1.2	27	0.32
	21	0.37		21	0.35
1 1/2	27	0.36	1.3	27	0.34
	21	0.39		21	0.375
1 5/8	27	0.38	1.4	27	0.35
	21	0.42		21	0.40
1 3/4	27	0.40	1.5	27	0.37
	21	0.44		21	0.41
1 7/8	27	0.43	1.6	27	0.38
	21	0.47		21	0.43
2	27	0.47	1.75	27	0.41
	21	0.52		21	0.46

Formula: $$\text{Application Rate In./Hr.} = \frac{110.0 \times \text{Sprinkler GPM}}{\text{Area of Wetted Circle, Sq. Ft.}}$$

Note: The application rate of Big Gun Sprinklers is independent of operating pressure when within the range in Tables 5.17 and 5.18.

1/ Maximum application rate is approximately 1.5 times the average application rate.

TABLE 5.17

PERFORMANCE OF NELSON MODEL 200

	Ring Nozzle Size, Inches																				
	1 1/4			1 3/8			1 1/2			1 5/8			1 3/4			1 7/8			2		
		Dia.Ft.			Dia.Ft.			Dia.Ft.			Dia.Ft.			Dia.Ft.			Dia.Ft.			Dia.Ft.	
P.S.I.	GPM	27°	21°	GPM	27°	21°	GPM	27°	21°	GPM	27°	21°	GPM	27°	21°	GPM	27°	21°	GPM	27°	21°
80	290	370	352	380	400	380	445	420	399	515	440	418	590	455	432	---	---	---	---	---	---
90	310	380	361	405	415	394	475	435	413	545	455	432	625	470	447	715	485	461	855	505	480
100	325	390	371	425	425	404	500	445	423	575	465	442	660	480	456	755	500	475	900	520	494
110	340	400	380	445	435	413	525	455	432	605	475	451	695	490	466	790	510	485	945	535	508
120	355	410	390	465	445	423	545	465	442	630	485	461	725	500	475	825	520	494	985	545	518
130	370	415	394	485	450	428	565	470	447	655	490	466	755	505	480	860	525	499	1025	550	523

	Taper Bore Nozzle Size, Inches																				
	1.05			1.2			1.3			1.4			1.5			1.6			1.75		
80	290	380	361	380	410	390	445	430	409	515	450	428	590	470	447	---	---	---	---	---	---
90	310	390	371	405	425	404	475	445	423	545	465	442	625	485	461	715	505	480	855	535	508
100	325	400	380	425	440	418	500	460	437	575	480	455	660	500	475	755	520	494	900	550	523
110	340	410	390	445	450	428	525	470	447	605	495	470	695	515	489	790	535	508	945	565	537
120	355	420	399	465	460	437	545	480	456	630	505	480	725	530	504	825	550	523	985	580	551
130	370	425	404	485	465	442	565	485	461	655	515	489	755	540	513	860	560	532	1025	590	561

TABLE 5.18

PERFORMANCE OF 104C/105C RAIN GUNS--23° TRAJECTORY

Elbow PSI	Ring Orifice, Size, Inches													
	.870"		.990"		1.000"		1.201"		1.293"		1.380"		1.450"	
	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.
60	110	264	142	284	185	300	226	318	275	335	324	352	385	365
70	118	275	154	295	200	314	243	332	295	350	353	367	418	383
80	127	285	164	306	213	326	263	345	315	364	374	383	447	398
90	136	295	175	315	227	337	276	358	336	378	400	396	475	414
100	142	305	185	326	238	348	290	371	352	390	422	409	500	425
110	150	315	195	335	250	357	305	382	372	402	441	421	525	438
120	157	322	202	344	259	366	323	392	392	412	465	431	550	450

Elbow PSI	Straight Bore, Size, Inches													
	.690"		.790"		.890"		.990"		1.090"		1.190"		1.290"	
	GPM	Dia	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.	GPM	Dia.
60	110	269	142	292	185	313	226	329	275	348	331	366	390	385
70	118	281	154	304	199	324	245	347	295	363	354	381	418	400
80	127	291	164	316	214	336	263	357	315	375	374	395	447	414
90	136	300	177	325	227	347	276	367	336	390	400	410	475	427
100	142	310	185	334	235	357	290	377	352	400	422	420	500	440
110	150	320	195	342	249	365	305	386	372	410	444	430	525	450
120	157	330	202	351	262	375	323	395	392	420	465	440	550	460

TABLE 5.19

TRAVEL SPEED IN FT./MIN.

Operation	Set Time	Travel Length Per Set in Feet								
		500	600	700	800	900	1000	1100	1200	1300
4 sets/day	5 hr. + 1 hr. for move	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3
3 sets/day	7 hr. + 1 hr. for move	1.2	1.4	1.7	1.9	2.1	2.4	2.6	2.9	3.1
2 sets/day	11 hr. + 1 hr. for move	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0
1 set/day	23 hr. + 1 hr. for move	---	---	0.5	0.6	0.7	0.7	0.8	0.9	1.0

TABLE 5.20

TRAVEL LANE SPACING IN FEET

Sprinkler Wetted Diameter (feet)	Percent of Wetted Diameter						
	50	55	60	65	70	75	80
	Wind over 10 mph		Wind up to 10 mph		Wind up to 5 mph		No wind
200	100	110	120	130	140	150	160
250	125	137	150	162	175	187	200
300	150	165	180	195	210	225	240
350	175	192	210	227	245	262	280
400	200	220	240	260	280	300	320
450	225	248	270	292	315	338	360
500	250	275	300	325	350	375	400
550	275	302	330	358	385	412	440
600	300	330	360	390	420	---	---

TABLE 5.21

DEPTH OF WATER APPLIED BY
TRAVELING SPRINKLERS (INCHES)

Sprinkler (GPM)	Average Wetted Diameter (Feet)	*Spacing of Travel Lane (Feet)	Travel Speed (Feet per Minute) 0.5	1	2	4
100	260	140 min.	2.3	1.1	0.6	0.3
		190 max.	1.7	0.8	0.4	0.2
200	320	170 min.	3.8	1.9	0.9	0.5
		240 max.	2.7	1.3	0.7	0.3
300	370	200 min.	4.8	2.4	1.2	0.6
		270 max.	3.6	1.8	0.9	0.4
400	410	220 min.	5.8	2.9	1.5	0.7
		310 max.	4.1	2.1	1.0	0.5
500	440	240 min.	6.7	3.3	1.7	0.8
		330 max.	4.8	2.4	1.2	0.6
600	470	260 min.	7.4	3.7	1.8	0.9
		350 max.	5.5	2.7	1.4	0.7
700	500	270 min.	8.3	4.1	2.1	1.0
		370 max.	6.1	3.0	1.5	0.8
800	520	280 min.	9.1	4.6	2.3	1.1
		390 max.	6.6	3.3	1.6	0.8
900	530	290 min.	9.9	5.0	2.5	1.2
		400 max.	7.2	3.6	1.8	0.9
1000	540	300 min.	10.7	5.3	2.7	1.3
		400 max.	8.0	4.0	2.0	1.0

Formula: Average depth applied in inches = $\frac{\text{1.6 x Sprinkler GPM}}{\text{Lane spacing ft. x travel speed ft./min.}}$

*Minimum travel lane based on 55% of wetted diameter and maximum travel based on 75% of wetted diameter.

TABLE 5.22

FLEXIBLE IRRIGATION HOSE
PRESSURE LOSS PER 100 FEET OF LENGTH